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Rate of Spread and Effect on Yield of Potato Virus Diseases

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RATE OF SPREAD AND EFFECT ON YIELD OF POTATO VIRUS DISEASES

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INTRODUCTION

It is well known that virus diseases are responsible for decreases in yield in the potato crop, and it has been shown that some virus diseases depress the yield more than others and that the degree of reduction is influenced by climatic conditions. It, however, was not known, when this study was undertaken, how much loss might be expected from a certain percentage of seed tuber infection with a particular disease. It was considered of value to know what percentage of disease may be thus present without apparent reduction in yield, and also to know whether yield reduction by a certain virus disease will be more or less in Maine than it will be elsewhere where Maine seed stocks are planted.

The seed-potato certification regulations of the various seed-producing states permit only relatively low percentages of the virus diseases in certified seed potatoes. The tolerance is not necessarily based on scientific facts pertaining to the performance of seed potatoes having certain amounts of virus disease. Since it was not known how much a certain amount of disease may be expected to reduce the crop when grown in different regions, the regulations regarding the amount of virus diseases permitted in certified seed potatoes appear to be based on the assumption that the presence of even small amounts of a disease may materially reduce the crop that is produced. This common belief has led many seed buyers to be unduly critical regarding the amount of virus disease that is present in the seed potatoes that are purchased.

Some of the studies described in this bulletin were begun in 1924, at a time when the control of the spread of mild mosaic was a major problem in Aroostook County, Maine, and refer to the spread of virus diseases year by year. Also, during the five-year

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period 1926 to 1930, duplicate diseased seed stocks were grown for comparison as to yield rate at Peconic, Long Island, New York, and at Presque Isle, Maine. After about the year 1930, there followed a period when the control of virus diseases seemed to be of little importance. The spindle tuber disease had been eliminated from most of the seed stocks in Maine and the spread of mild mosaic was less serious, especially for the growers of certified seed potatoes. Proximity studies conducted in Aroostook County for a period of 13 years prior to 1937 showed that the spread of leafroll, spindle tuber, and rugose mosaic in most cases was quite negligible, excepting for the year 1929. However, beginning with 1937 the situation became different. Not only was mild mosaic widely disseminated but leafroll, spindle tuber, and rugose mosaic as well. In some cases relatively healthy seed stocks grown in 1937 developed from 50 to 80 per cent leafroll when planted in 1938 (2, p. 297). This condition prompted the writers to repeat some of their studies on the effect of different amounts of virus diseases on the yield.

There are four species of aphids which commonly infect the potato fields of Aroostook County and disseminate the virus diseases referred to in this paper. These are the green peach aphid (*Myzus persicae* Sulz.), the pink and green potato aphid (*Macrosiphum solanifolii* Ashm.), the buckthorn aphid (*Aphid abbreviata* Patch.), and the foxglove aphid (*Myzus pseudosolani* Theob.). Of these the green peach aphid appears to be, potentially at least, the most effective vector of the potato virus diseases that were studied. Aphids also, by their feeding, may injure the potato plants and thus materially reduce the crop.

YIELD REDUCTION BY COMPLETE INFECTION IN MAINE AND NEW YORK

Studies conducted in 1924 in Aroostook County, Maine, showed that mild mosaic in completely infected Green Mountain potatoes reduced the yield 8 to 15 per cent below the yield of healthy stocks of the same commercial strain (6, p. 57). Rugose mosaic reduced the Green Mountain yield 50 per cent. Spindle tuber in Green Mountains and Irish Cobblers reduced the yield 20 per cent (6, p. 57). In experiments conducted in 1925 with Green Mountain potatoes, complete infection by mild mosaic and spindle tuber re-

duced the yield 25 per cent and complete infection by rugose mosaic reduced the yield about 60 per cent (6, p. 57). Leafroll hills were found to yield only from 15 to 40 per cent as much as healthy hills (5, p. 45).

In 1928 an experiment was conducted to obtain additional information upon the effect of complete infection by certain virus diseases on the yield of Green Mountain and Triumph (Bliss Triumph). For this experiment 4-ounce tubers from diseased hills were selected and cut in half. The halves of each tuber were planted respectively at Presque Isle, Me., and at Peconic, Long Island, New York. One hundred tubers with each disease were planted. Hills were spaced 14 inches apart in the row and were harvested and weighed separately.

All of the seed stocks undoubtedly contained latent mosaic (virus X) in masked form. The Green Mountain seed stocks used in this experiment were as follows: "healthy" (with only the latent mosaic), giant hill, mild mosaic, leafrolling mosaic, crinkle mosaic, rugose mosaic, spindle tuber, and leafroll. Giant hill apparently is not a virus disease. It is considered by the present authors to be a bud mutation from the Green Mountain variety. Mild mosaic as described by Schultz and Folsom (7, p. 46) is a combination of latent mosaic (virus X or simple mosaic = Solanum virus 1 of Smith) and virus A or Solanum virus 3 of Smith (9, p. 344 and p. 355). Leafrolling mosaic as described by Schultz and Folsom (7, pp. 51-52) is a combination of latent mosaic and another virus, the identity of which is not known. Crinkle mosaic is considered to be a severe form of mild mosaic, possibly caused by virus A in combination with a severe type of latent mosaic. Rugose mosaic as described by Schultz and Folsom (7, pp. 52-53) is latent mosaic in combination with the "virus Y" or Solanum virus 2 of Smith (9, p. 394).

The results of this experiment are recorded in Table 1. It may be noted that the plants having giant hill yielded somewhat more than the healthy stock when grown in Maine. Folsom *et al.* (6, p. 73) likewise found that the presence of giant hill may slightly increase the yield in Maine. This abnormality causes later maturity which may be accompanied by a slightly higher yield, especially when killing frosts occur late in the season. It also is associated with resistance to killing by fall frosts, which characteristic sometimes adds to the length of life compared with that of earlier matur-

TABLE 1

Comparison of the effect on yield of certain virus diseases, at 100 per cent seed tuber incidence, in the Green Mountain and Triumph varieties when grown at Presque Isle, Maine, and at Peconic, Long Island, New York, in 1928

Variety	Disease	Yield per acre[1]				Decrease in yield compared with healthy stock					
		Maine		New York		Maine			New York		
		Barrels	Bushels	Barrels	Bushels	Barrels	Bushels	%	Barrels	Bushels	%
Green Mountain	Healthy	175	480	99	272	—	—	—	—	—	—
	Giant hill	179	493	73	200	+ 4[2]	+13[2]	+ 3[2]	26	72	26
	Spindle tuber	144	395	57	157	31	85	18	42	115	42
	Mild mosaic	136	375	73	200	39	105	22	26	72	26
	Leafrolling mosaic	127	350	88	241	48	130	27	11	31	11
	Crinkle mosaic	94	258	69	189	81	222	46	30	83	30
	Rugose mosaic	87	240	66	182	88	240	50	33	90	33
Triumph	Leafroll	95	262	47	129	80	218	45	52	143	53
	Healthy	151	415	156	430	—	—	—	—	—	—
	Mild mosaic	117	322	118	325	34	93	22	38	105	24
	Spindle tuber	101	279	72	197	50	136	33	84	233	54
	Leafroll	66	180	55	153	85	235	56	101	277	64

[1] The yields here are based on the mean of 100 plants for each test, each hill bein g harvested and weighed separately.
[2] Giant hill in Maine gave slightly higher yields than the healthy stock.

ing plants. The diseases spindle tuber, mild mosaic, leafrolling mosaic, crinkle mosaic, rugose mosaic, and leafroll caused significant decreases in yield in all instances. Spindle tuber, mild mosaic, and leafroll in both Green Mountain and Triumph produced greater yield reductions, on the percentage basis, on Long Island than in Maine, while leafrolling, crinkle, and rugose mosaic in the Green Mountain variety produced greater reduction in Maine than on Long Island. It is of interest that healthy Triumph yielded better on Long Island than Green Mountain.

Experiments conducted by Eddins (4) in Florida in 1940 revealed that when 100 per cent of the plants were from leafroll infected seed tubers the yield was 40 per cent of that obtained from disease-free seed stock.

YIELD REDUCTION IN RELATION TO PERCENTAGE OF INCIDENCE OF VIRUS DISEASES

The data in Table 1 show that a decrease in yield resulted from complete infection by a virus disease. Such data, however, do not mean that a reduction in yield necessarily occurs from partial infection and they do not show the maximum per cent of disease that may be present before a significant reduction in the crop may be expected.

Previously reported studies conducted in Maine have shown that the loss in yield is not always in proportion to the number of diseased tubers in the seed stock. In experiments conducted at Aroostook Farm in 1924, 20 per cent mild mosaic and 34 per cent spindle tuber reduced the yield only 7 bushels per acre in comparison with yields from seed stock with 3 per cent mild mosaic and 7 per cent spindle tuber. When the seed stock contained 41 per cent mild mosaic and 100 per cent spindle tuber the yield was reduced 76 bushels per acre or nearly 11 times the loss resulting from the moderately infected seed stock (6, p. 61, Table 1).

In the same experiment with another strain of Green Mountain potatoes, a seed stock with 24 per cent mosaic and 20 per cent spindle tuber gave a yield 41 bushels per acre less than that of a seed stock having 10 per cent mosaic and 8 per cent spindle tuber (6, p. 63, Table 2). When the per cent mild mosaic and spindle tuber in the seed stock was 99 and 24 per cent, respectively, the

yield was 42 bushels per acre or only 1 bushel more than for the seed stock with 24 per cent mosaic and 20 per cent spindle tuber.

Data of a very similar nature were secured also in experiments conducted on Aroostook Farm in 1928 to 1931 (8, pp. 18-19, Tables 10 and 11).

In view of these previously reported inconsistencies, it may not be surprising if the results reported here with seed stocks from different commercial fields are not consistent. Such tests were made with respect to mild mosaic in the Green Mountain variety and spindle tuber in the Irish Cobbler variety, with duplicate tests in Maine and New York, in 1927 to 1930. More recently, tests were made with several diseases in several varieties with the disease percentage controlled by mixing healthy and diseased stock in various proportions.

MILD MOSAIC IN THE GREEN MOUNTAIN VARIETY IN MAINE AND IN NEW YORK, 1926 TO 1930

Experiments were conducted during the five-year period 1926 to 1930 to determine the reduction in yield that might result from the presence of different percentages of mild mosaic in the same stocks when planted in Maine and in New York. Seed was selected (1) from fields which appeared to be practically free of all virus disease, (2) from fields with 2 to 5 per cent virus disease, mostly mild mosaic, representing seed stocks accepted for certification but supposedly not the best, and (3) from fields rejected because of the presence of more disease than was tolerated by the certification regulations.

Each of the samples of potatoes selected for this experiment was divided into two similar lots, one of which was planted on Aroostook Farm, Presque Isle, Maine, and the other at Peconic, Long Island, New York.

The results are summarized in Table 2. The number of diseased plants found in the field at the time of certification was not an accurate indication of the percentage of disease in the seed stock when it was planted the following year (Table 2). Usually the seed stocks carried from 3 to 10 times this amount of disease, as was indicated by the field readings made the following season. This was due in part to the fact that some spread of disease occurred in the

TABLE 2

Effect on yield of different percentages of mild mosaic in the Green Mountain variety when grown at Presque Isle, Maine, and at Peconic, Long Island, New York

Year	Disease in seed stock[1]	Disease reading in test[2]	Yield per acre[3]				Reduction in yield[4]			
			Maine		New York		Maine		New York	
	Per cent	Per cent	Bushels	Barrels	Bushels	Barrels	Barrels	Per cent	Barrels	Per cent
1926	0.4	3.9	307± 1.09	112± .40	226±3.09	83±1.12	—	—	—	—
	1.9	8.0	294± 3.39	106±1.23	221±1.37	80± .50	6	5.3[5]	3	3.6
	8.7	50.0	278± 2.42	101± .88	177±6.53	64±2.37	11	9.8[5]	19	22.9[5]
	20.0	68.0	257± 4.15	93±1.51	149±3.19	54±1.16	19	17.0[5]	29	34.9[5]
1927	0	0.9	392± 4.02	143±1.46	225±4.20	82±1.53	—	—	—	—
	1.3	5.0	377± 2.99	137±1.09	209±3.38	76±1.23	6	4.2[5]	6	7.3[5]
	5.6	27.6	366± 3.12	133±1.13	195±5.30	71±1.93	10	7.0[5]	11	13.4[5]
	9.0	28.0	367± 4.75	134±1.73	178±3.85	65±1.40	9	6.3[5]	17	20.7[5]
1928	0	2.8	376± 5.09	137±1.85	199±4.46	72±1.62	—	—	—	—
	3.0	15.8	358± 5.40	130±1.96	206±3.96	75±1.44	7	5.1	+ 3[6]	+ 4.2[6]
	9.0	79.4	280± 3.12	102±1.13	143±5.33	52±1.94	35	25.5[5]	20	27.8[5]
1929	0	5.0	357± 3.73	130±1.36	103±5.01	38±1.82	—	—	—	—
	2.0	9.0	342± 3.53	124±1.28	85±2.12	31±0.77	6	4.6	7	18.4[5]
	3.0	12.0	362± 4.62	132±1.68	69±2.99	25±1.08	+ 2[6]	+ 1.5[6]	13	34.2[5]
1930	0	6.6	427±16.92	155±6.15	337±5.67	123±2.06	—	—	—	—
	2.0	22.0	416± 6.27	151±2.28	307±4.67	112±1.70	4	2.6	11	8.9[5]
	7.0	55.0	350± 7.24	127±2.63	267±6.51	97±2.37	28	18.1[5]	26	21.1[5]

[1] Disease apparent in the seed-stock fields when examined by seed certification inspectors.
[2] Average percentage disease evident in the plants grown in Maine and Long Island from the different seed stocks. The disease was mostly mild mosaic with a trace of leafroll. Difference from amount in seed-stock fields chiefly due to the spread which did not show before harvesting.
[3] Every yield record is based on eight replicated plots each containing 100 feet of row.
[4] Probably due to disease that has spread but is not yet apparent, as well as to disease apparent in test.
[5] Reduction statistically significant; also corresponding barrel reductions.
[6] Increase.

TABLE 3

Reduction in yield rate relative to percentage of mild mosaic, data based on table 2.

Year	Disease reading in test	Difference in disease reading from lowest per-cent (D)	Reduction in yield per acre		Percentage reduction in yield		Ratios			
			In Maine (RM)	In N. Y. (RN)	In Maine (PM)	In N. Y. (PN)	RM/D	RN/D	PM/D	PN/D
	Per cent		Bu.	Bu.	Per cent	Per cent				
1926	3.9	—								
	8.0	4.1	13	5	4.2	2.2	3.2	1.2	1.0	0.5
	50.0	46.1	29	49	9.4	21.7	0.6	1.1	0.2	0.5
	68.0	64.1	50	77	16.3	34.1	0.8	1.2	0.3	0.5
1927	0.9	—								
	5.0	4.1	15	16	3.8	7.1	3.7	3.9	0.9	1.7
	27.6	26.7	26	30	6.6	13.3	1.0	1.1	0.2	0.5
	28.0	27.1	25	47	6.4	20.9	0.9	1.7	0.2	0.8
1928	2.8	—								
	15.8	13.0	18	+ 7[1]	4.8	3.5[1]	1.4	+0.5[1]	0.4	+0.3[1]
	79.4	76.6	96	56	25.5	28.1	1.3	0.7	0.3	0.4
1929	5.0	—								
	9.0	4.0	15	18	4.2	17.5	3.8	4.5	1.1	4.4
	12.0	7.0	+ 5[1]	34	+ 1.4[1]	33.0	+1.7[1]	4.9	+0.2[1]	4.7
1930	6.6	—								
	22.0	15.4	9	30	2.1	8.9	0.6	1.9	0.1	0.6
	55.0	48.4	77	70	18.0	20.8	1.6	1.4	0.4	0.4

[1]Increase

field during the growing season and that the symptoms from such spread could not yet be apparent to the inspectors when they made the examinations. It is possible, also, that in some cases mild mosaic was masked and thus was not detected at the time of making the certification inspection. Whatever the explanation, the certification records frequently do not give a reliable indication of the quality of seed purchased. This emphasizes the value of having available advance readings made in the greenhouse or in Florida.

All of the stocks yielded more in Maine than on Long Island. Except in New York in 1928 and in Maine in 1929, the stock having the least amount of virus disease produced the highest yield. In general the presence of mild mosaic in a stock reduced the yield more on Long Island than in Maine, especially on the percentage basis.

In order to see whether the reduction in yield per acre is proportional to the increase in disease percentage, some of the data in Table 2 have been transferred or used to form Table 3. Here it is evident that the reduction in bushels for each percentage unit of increase in disease (ratios RM/D and RN/D) is not the same at the several levels of infection. In 5 of the 10 comparisons, the reduction is proportionally much greater for a small percentage of infection than for the larger ones. In only one instance, RM/D for 1930, is the ratio materially larger at the higher level of infection. Therefore these data undermine rather than support the idea that mild mosaic reduces the yield in greater degree with every increase in the percentage of disease in the seed stock.

Spindle Tuber in the Irish Cobbler Variety in Maine and New York, 1927 to 1930

The Irish Cobbler variety does not contract mild mosaic under field conditions but is susceptible to the field spread of spindle tuber. An experiment was conducted during the four-year period 1927 to 1930 to determine the effect on yield of different percentages of spindle tuber in Irish Cobbler stocks when grown in Maine and on Long Island.

For this experiment seed stocks were selected from fields showing different percentages of spindle tuber. Fortunately the percentage of disease shown by the field readings made by the certi-

fication inspectors corresponded quite well with the amount of disease actually found when the seed was planted the following year. This was because spindle tuber in the Irish Cobbler variety did not spread as extensively as did mild mosaic in the Green Mountain variety.

It may be noted from the data in Table 4 that in general the highest yields occurred in the plots having the least amount of spindle tuber. This, however, was not always the case. In 1929 in Maine, seed stocks with 3.9 per cent and with 18.4 per cent disease, respectively, yielded slightly more than did the seed stock with no disease.

In the experiments conducted in New York, the seed with the least amount of spindle tuber yielded, in all but one case, more than those that were infected. However, the seed stock with the highest percentage of disease did not always give the lowest yield rates. For instance, in 1927 the seed stock with 11 per cent spindle tuber gave higher yields than that with 6.6 per cent spindle tuber. In 1928, the seed stock with 15.0 per cent spindle tuber yielded at the rate of 307 bushels per acre compared with only 293 bushels per acre for the seed stock which had 10.8 per cent spindle tuber. Likewise, in 1929 the seed with only 3.9 per cent spindle tuber yielded 4 bushels less per acre than did that with 18.4 per cent disease. It is thus seen that the yields were not consistently less for the higher percentages of spindle tuber.

It should be noted also from the data in Table 4 that with one exception the reduction in the yield for a given percentage of spindle tuber was greater on Long Island than it was in Maine. The presence of a higher temperature and less rainfall on Long Island during the growing season apparently increased the yield loss caused by the presence of spindle tuber in the seed stock.

In order to determine whether the reduction in yield caused by the spindle tuber disease was proportional to the increase in the disease percentage, some of the data in Table 4 have been used to form Table 5.

It may be observed from the data in Table 5 that the proportional reduction in yield in New York was consistently less as the actual amount of the disease increased. In other words, a doubling or trebling of the disease content in the seed planted did not result in corresponding proportionate losses in yield. It would seem that this might be explained on the basis that the plants with spindle

TABLE 4

Effect on yield of different percentages of spindle tuber in the Irish Cobbler variety when grown at Presque Isle, Maine, and at Peconic, Long Island, New York, for the years 1927 to 1930

Year	Disease in seed stock[1]	Disease reading in test[2]	Yield per acre[3]				Reduction in yield			
			Maine		New York		Maine		New York	
			Bushels	Barrels	Bushels	Barrels	Barrels	Per cent	Barrels	Per cent
1927	0	0	393±3.60	143±1.31	244± 7.15	89±2.60	—	—	—	—
	3.6	6.6	384±5.51	140±2.00	188± 6.23	69±2.27	3	2.1	20	22.5
	5.8	11.0	372±6.08	136±2.21	209± 5.62	76±2.04	7	4.9	13	14.6
1928	0	3.7	371±6.02	135±2.19	320± 3.73	116±1.36	—	—	—	—
	4.8	10.8	350±4.40	127±1.60	293± 5.51	106±2.00	8	5.9	10	8.6
	13.0	15.0	337±8.00	123±2.94	307± 4.53	111±1.65	12	8.9	5	4.3
1929	0	0	300±2.16	109± .785	99± 5.38	36±1.95	—	—	—	—
	5.0	3.9	304±2.77	110±1.01	85± 5.52	31±2.00	+ 1	+ .9	5	13.9
	12.0	18.4	303±2.16	110± .785	89± 3.98	32±1.45	+ 1	+ .9	4	14.1
1930	0	0.6	393±6.76	143±2.46	365±10.65	133±3.87	—	—	—	—
	0.4	1.1	384±7.05	140±2.56	382± 9.35	139±3.40	3	2.1	+ 6	+ 4.5
	62.0	68.0	357±4.02	130±1.46	280± 9.72	102±3.53	13	9.1	31	23.3

[1] Disease apparent in the seed-stock fields when examined by seed certification inspectors.
[2] Average percentage disease evident in the plants grown in Maine and Long Island from the different seed stocks.
[3] Every yield record is based on eight replicated plots each containing 100 feet of row.

TABLE 5

Reduction in yield rate relative to percentage of spindle tuber, data based on table 4.

Year	Disease reading in test	Difference in disease reading from lowest per cent (D)	Reduction in yield per acre		Reduction in yield rate in per cent		Ratios			
			In Maine (RM)	In N. Y. (RN)	In Maine (PM)	In N. Y. (PN)	RM/D	RN/D	PM/D	PN/D
			Bu.	Bu.	Per cent	Per cent				
1927	0	—								
	6.6	6.6	9	56	1.8	23.0	1.1	8.5	.3	3.5
	11.0	11.0	19	35	4.9	14.3	1.7	3.2	.4	1.3
1928	3.7	—								
	10.8	7.1	21	27	5.7	8.4	3.0	3.8	.8	1.2
	15.0	11.3	34	13	9.2	4.1	3.0	1.5	.8	.4
1929	0	—								
	3.9	3.9	+ 4[1]	14	+1.3[1]	14.1	+1.0[1]	3.6	+.3[1]	3.6
	18.4	18.4	+ 3[1]	10	+1.0[1]	10.1	+0.2[1]	.5	+.05[1]	.5
1930	0.6	—								
	1.1	.5	9	+17	2.3	+ 4.7	18.0	+34.0	4.6	+ .9
	68.0	67.4	36	85	9.2	23.3	.5	1.3	.1	.3

[1]Increase

tuber were less competitive for the available moisture and therefore the healthy plants were permitted to grow and develop better.

In Maine the proportional reduction in the yield, caused by an increase in the amount of disease, was not consistent. It should be observed also that for 1929 and 1930, an increase in the amount of spindle tuber in the seed stock resulted in a relatively small loss in yield.

Eddins in 1940, in studies conducted with the Katahdin variety in Florida, found that there was no significant reduction in the total yield of tubers in plantings containing 32 per cent or less spindle tuber. The average yield, however, was 52.7 bushels per acre less from the 100 per cent spindle tuber infected seed than for that free of the disease (4, p. 106).

Leafroll in the Irish Cobbler and Green Mountain Varieties in Maine in 1938

An experiment was conducted in Maine in 1938 to determine the effect on yield of different percentages of leafroll in the Irish Cobbler and Green Mountain varieties.

In this experiment the healthy and diseased seed pieces were mixed before being planted by hand, thus obtaining a random distribution of healthy and diseased plants as well as the desired disease content.

The results of the experiment with the Irish Cobbler variety have been summarized in Table 6. The presence of 10 per cent leafroll reduced the yield only 2.3 barrels (6.5 bushels) or about 2 per cent. Twenty per cent leafroll in the seed stock caused a reduction of 11.1 barrels (30.7 bushels) which is 9.6 per cent of the crop. This reduction in yield is nearly significant for these data at the 5 per cent level, odds being 18.80 to 1. Thirty per cent leafroll caused a reduction of 9.9 barrels (27.2 bushels) or 9.4 per cent. The odds that 30 per cent leafroll reduced the yield significantly are 53.95 to 1. When the Irish Cobbler seed stock was completely infected, the yield was reduced 64.3 per cent in comparison with the crop produced by a healthy seed stock.

The lack of significance up to 20 per cent disease does not mean that the lower percentages of leafroll lacked effect upon the yield rate; it merely prevents our proving beyond question, under the

TABLE 6

Yield of Irish Cobbler variety with different percentages of leafroll,[1] 1938

Per cent leafroll	Yield per acre[2]		Reduction in yield per acre			Ratio of per cent loss to per cent disease
	Barrels	Bushels	Barrels	Bushels	Per cent	
0	114.8±2.57	315.9±6.29	—	—	—	—
10	112.5±2.79	309.4±7.77	2.3	6.5	2.0	0.20
20	103.7±2.76	285.2±7.91	11.1	30.7	9.6	0.48
30	104.9±1.20	288.7±2.13	9.9	27.2	9.4	0.31
100	40.9±2.31	112.6±6.18	73.9	203.3	64.3	0.64

[1] The different percentages of leafroll were obtained by the addition of seed pieces from tubers affected with net necrosis to a healthy seed stock.
[2] Every yield rate is based on 4 randomized plots each consisting of 115 feet of row with 100 seed pieces planted by hand, 14 inches apart in the row.

conditions of the test, that they had enough effect to overcome the statistical effect of plot variation.

The last column of Table 6 indicates that there was a general increase in the yield-depressing effect of leafroll as the percentage increased; the effect increased from 0.20 per cent yield loss per 1 per cent leafroll at the 10 per cent leafroll level up to 0.64 per cent yield loss per 1 per cent leafroll at the 100 per cent level.

The data for the effect on yield of different percentages of leafroll in the Green Mountain variety in 1938 are summarized in Table 7. In this experiment a significant reduction occurred in the yield when the seed stock contained 12 per cent leafroll. When 100 per cent of the plants were infected, the yield was reduced 69.2 per cent in this variety compared with a reduction of 64.3 per cent when all of the plants were infected in the case of the Irish Cobbler variety.

The last column of Table 7 indicates that each per cent of leafroll had about the same effect in per cent yield loss at all levels of leafroll incidence. If there was any trend, it was toward less effect at the higher percentages of disease.

MILD MOSAIC, RUGOSE MOSAIC, AND SPINDLE TUBER IN THE GREEN MOUNTAIN VARIETY, AND LEAFROLL IN THE GREEN MOUNTAIN, IRISH COBBLER, AND CHIPPEWA VARIETIES, IN MAINE IN 1939

The studies of the effect of different percentages of virus diseases on yield were continued in 1939 at Presque Isle, Maine. The

experiments of 1939 included mild mosaic, rugose mosaic, spindle tuber, and leafroll in the Green Mountain variety, as well as leafroll in the Irish Cobbler and Chippewa varieties.

TABLE 7

Yield rate of Green Mountain variety with different percentages of leafroll,[1] *1938*

Per cent leafroll	Yield per acre[2]		Reduction in yield per acre			Ratio of per cent loss to per cent disease
	Barrels	Bushels	Barrels	Bushels	Per cent	
1-2	146.2±2.96	402.1±8.04	—	—	—	—
7	136.4±2.30	374.9±6.64	9.8	27.2	6.7	0.96
12	125.5±1.20	345.2±3.40	20.7	56.9	14.2	1.18
17	121.2±2.65	333.2±7.38	25.0	68.9	17.1	1.01
25	121.5±2.24	334.1±7.45	24.7	68.0	16.9	0.68
31	112.7±2.28	310.2±6.39	33.5	91.9	22.9	0.74
37	120.6±2.84	331.8±7.61	25.6	70.3	17.5	0.47
52	103.4±2.16	284.0±5.96	42.8	118.1	29.3	0.56
100	45.0±1.67	124.0±4.60	101.2	278.1	69.2	0.69

[1] The different percentages of leafroll were obtained by the addition of seed pieces from tubers affected with net necrosis to a seed stock containing 2 per cent leafroll.
[2] Every yield rate is based on 10 randomized plots each consisting of 115 feet of row with 100 seed pieces planted by hand, 14 inches apart in the row.

The results of the experiments conducted in 1939 are summarized in Table 8. The data show that the different diseases, if present in large amounts, may affect the yield materially. Mild mosaic in the Green Mountain variety reduced the yield less than did rugose mosaic, spindle tuber or leafroll. With 100 per cent of infection, mild mosaic reduced the yield in Green Mountain 30.7 per cent compared with a reduction of 62.8 per cent from rugose mosaic, 63.4 per cent from spindle tuber, and 62.4 per cent from leafroll. Leafroll when present in all of the plants reduced the yield less in the Irish Cobbler variety than in the Green Mountain and Chippewa varieties.

The lowest section of Table 8 gives the reduction in per cent of yield for each per cent of disease. In this respect mild mosaic in Green Mountains, leafroll in Irish Cobblers with one exception, and in Chippewas reduced the yield much less at the 4, 12, and 20 per cent levels than at 30 and 100 per cent, while rugose mosaic, spindle tuber, and leafroll in Green Mountains affected the yield at least as much at these lowest percentages.

It should be noted from the data in Table 8 that 4 and 12 per cent leafroll in some cases resulted in slight increases in yields. This occurred probably because in 1939 there was not enough moisture to properly mature a good stand of healthy plants. The diseased plants, if present, died early in the season and allowed the remaining healthy plants to continue to grow and produce a larger crop proportionally than they probably would have produced had all plants remained green throughout the growing season.

The fact that Irish Cobblers in 1939, as they had in 1938, lost in per cent of yield more for each per cent of leafroll at the higher percentage levels than at the lower, is more or less in agreement

TABLE 8

Effect on potato yield of different percentages of virus diseases, 1939[1]

Yield data expressed as:	Variety	Disease	Yields from plantings with specified initial percentages of disease[3]					
			Trace	4%	12%	20%	30%	100%
Bushels per acre	Gr. Mt.	Mild mosaic	345.8	343.0	343.1	337.5	313.8	239.5
	Gr. Mt.	Rugose mosaic	381.3	363.0	342.8	347.0	327.4	141.8
	Gr. Mt.	Spindle tuber	329.4	314.2	293.9	289.6	281.1	120.4
	Gr. Mt.	Leafroll	370.8	380.3	331.2	333.4	317.5	139.5
	I. Cob.	Leafroll	230.0	235.3	238.6	222.8	222.1	152.8
	Chippewa	Leafroll	333.4	332.8	336.5	318.3	300.3	110.7
Barrels per acre	Gr. Mt.	Mild mosaic	126.0	125.1	125.1	123.0	114.4	87.3
	Gr. Mt.	Rugose mosaic	138.9	132.3	124.9	126.5	119.3	51.7
	Gr. Mt.	Spindle tuber	120.1	114.5	107.1	105.5	102.5	43.9
	Gr. Mt.	Leafroll	135.2	138.6	122.0	121.5	115.8	50.9
	I. Cob.	Leafroll	83.8	85.8	86.9	81.2	80.9	55.7
	Chippewa	Leafroll	121.1	120.9	122.2	115.6	109.2	40.2
Reduction in bbl. per acre	Gr. Mt.	Mild mosaic	—	0.9	0.9	3.0	11.6	38.7
	Gr. Mt.	Rugose mosaic	—	6.6	14.0	12.4	19.6	87.2
	Gr. Mt.	Spindle tuber	—	5.6	13.0	14.6	17.6	76.2
	Gr. Mt.	Leafroll	—	I [2]	13.2	13.7	19.4	84.3
	I. Cob.	Leafroll	—	I [2]	I [2]	2.6	2.9	28.1
	Chippewa	Leafroll	—	0.2	I [2]	5.5	11.9	80.9
Percentage reduction	Gr. Mt.	Mild mosaic	—	0.7	0.7	2.4	9.2	30.7
	Gr. Mt.	Rugose mosaic	—	4.8	10.1	8.9	14.1	62.8
	Gr. Mt.	Spindle tuber	—	4.7	10.8	12.2	14.7	63.4
	Gr. Mt.	Leafroll	—	I [2]	9.8	10.1	14.3	62.4
	I. Cob.	Leafroll	—	I [2]	I [2]	3.1	3.5	33.5
	Chippewa	Leafroll	—	0.2	I [2]	4.5	9.8	66.8
Ratio of per cent loss to per cent disease	Gr. Mt.	Mild mosaic	—	0.18	0.06	0.12	0.31	0.31
	Gr. Mt.	Rugose mosaic	—	1.20	0.84	0.45	0.47	0.63
	Gr. Mt.	Spindle tuber	—	1.18	0.90	0.61	0.49	0.63
	Gr. Mt.	Leafroll	—	I [2]	0.82	0.51	0.48	0.62
	I. Cob.	Leafroll	—	I [2]	I [2]	0.16	0.12	0.34
	Chippewa	Leafroll	—	0.05	I [2]	0.23	0.33	0.67

[1] Yield rate calculated from yields of 8 plots for each lot of seed compared. The plots were arranged in a magic square and each consisted of 50 hills spaced 1 foot apart in the row.

[2] "I" indicates an increase. All increases were too small to be significant.

[3] In bushels per acre.

with the conclusions of Tuthill and Decker (10) in New York. Their conclusions were based on yields of leafroll and healthy hills in the same field, by use of a formula developed by Blodgett (3). In New York the yields of healthy hills next to leafroll hills were increased, though not enough to prevent some loss in the aggregate even at low leafroll percentages. As the number of leafroll hills increased up to 40 per cent, there was an increase in the number of healthy hills that were next to leafroll hills. However, the yield reduction caused by the presence of leafroll was greater than the increase in yield which resulted in the healthy hills because of being in close proximity to the leafroll plants. The result was a greater net loss in the yield rate. The percentage of yield reduction for every per cent of disease (caluculated from their table 4) was as follows:

Leafroll per cent	10	20	30	40	50	60	70	80	90	100
Per cent yield reduction for each per cent leafroll	.37	.38	.38	.40	.41	.43	.45	.47	.50	.53

Thus the percentage yield loss for each per cent leafroll increased more slowly from levels of 10 to 50 per cent leafroll infection than from levels of 50 to 100 per cent.

Similarly, the greater yield loss by percentage in the Chippewas in Maine in 1939, at 30 and 100 per cent leafroll (Table 8), agreed more or less with the results of Tuthill and Decker. Their percentage of yield reduction for every per cent of disease in Chippewas was as follows:

Leafroll per cent	10	20	30	40	50	60	70	80	90	100
Per cent yield reduction for each per cent leafroll	.28	.29	.30	.31	.32	.34	.35	.37	.39	.41

YIELD REDUCTION IN RELATION TO SEASON

Maximum yields of potatoes are favored by relatively cool and moist seasons. In general, climatic conditions which prevail in Aroostook County, Maine, are favorable for potato culture. There are, however, occasional seasons in Maine when there is a deficiency

of moisture for the production of maximum yields. Under such conditions the plants infected with the virus diseases mature earlier than they normally do and there is a corresponding reduction in yield because of the smaller size of the tubers that are produced.

The data in Table 2 show the extent to which the yield may vary from season to season with seed stocks having different amounts of disease. The best Green Mountain seed stock included in the experiment in 1926 in Maine produced a yield of only 307 bushels or 112 barrels per acre, whereas in 1927 the yield was 392 bushels or 143 barrels per acre. The seasonal difference in yield was still greater in 1930 when the seed stock with 6.6 per cent mild mosaic yielded 427 bushels or 155 barrels per acre. The yield for the year 1930 was 120 bushels (43 barrels) more than that of 1926 and 35 bushels (12 barrels) more than that obtained in 1927.

Similar seasonal differences in yield occurred at Peconic, Long Island, New York, as can be seen also from the data in Table 2. In 1929, a Green Mountain seed stock with 5 per cent mild mosaic yielded only 103 bushels or 38 barrels per acre. In 1930, a seed stock with 6.6 per cent mild mosaic yielded 337 bushels or 123 barrels per acre. This difference in yield of 234 bushels or 85 barrels for these two seasons apparently was caused largely by the lack of soil moisture in 1929.

Large seasonal differences in yield occurred also in the experiments conducted with the Irish Cobbler variety for the years 1927 to 1930. The data in Table 4 show that the disease-free seed stock when planted in Maine yielded 393 bushels or 143 barrels per acre for the years 1927 and 1930, and only 300 bushels or 109 barrels for 1929.

The effect on yield of different percentages of spindle tuber in the Irish Cobbler variety grown in Peconic, New York, for the years 1927 to 1930 also is given in Table 4. These data show that the effect on yield of different amounts of spindle tuber varies for the different seasons. For instance, in 1927 a relatively good seed stock with 6.6 per cent spindle tuber yielded only 188 bushels or 69 barrels per acre. In contrast in 1928 a seed stock with 10.8 per cent spindle tuber yielded 293 bushels or 106 barrels per acre and a seed stock with 15 per cent spindle tuber yielded 307 bushels or 111 barrels per acre. It is thus seen that in 1928 the yields secured with seed stocks having a relatively high incidence of disease yielded more than the better seed stocks planted in 1927. Furthermore the

data in Table 4 show that in 1930 a very badly infected seed stock with 68 per cent spindle tuber yielded 280 bushels or 102 barrels per acre which is considerably more than the much better seed stocks yielded when grown in 1927 and 1929. It also should be noted from the data in Table 4 that the seed stocks with none and with 3.9 per cent spindle tuber yielded only 36 and 31 barrels per acre respectively in 1929 which is significantly lower than in other years with seed stocks having much higher percentages of the virus diseases.

Fluctuations in the climatic conditions during the same season and in the same locality as well as differences in the conditions between different localities may influence the yield greatly. When the moisture and temperature are more favorable early than later in the growing season, the early maturing varieties produce higher yields than the late maturing varieties. Likewise, the early maturing varieties may yield less than the late maturing varieties when the favorable growing conditions prevail only late in the season. The data in Table 1 show that in 1928 the early maturing Triumph variety yielded significantly more in Peconic, New York, than did the late maturing Green Mountain variety. However, in Maine where moisture and temperature were more favorable the Green Mountain variety yielded more than did the Triumph variety.

Likewise, giant hill, a late maturing mutant of the Green Mountain variety, yielded more in Maine in 1928 than did the standard Green Mountain variety because of the presence of favorable weather conditions late in the growing season. In New York, where the conditions were less favorable toward the end of the season, the Green Mountain variety yielded more than did the later maturing giant hill mutant.

VARIATION IN THE DISSEMINATION OF MILD MOSAIC, LEAFROLL, AND SPINDLE TUBER IN FIELD-EXPOSURE PLOTS FOR THE YEARS 1924 TO 1942

It has been stated previously in this paper that the spread of mild mosaic was a major problem in Aroostook County in 1924 when these studies were begun. Leafroll, at that time, was relatively unimportant and the spindle tuber disease had been practically eliminated.

Experiments were conducted during the 19-year period from 1924 to 1942 for the purpose of securing information regarding the spread of the different virus diseases in Aroostook County, Maine. For these experiments, seed potatoes which were completely infected with mild mosaic, leafroll, or spindle tuber were planted in single rows in fields planted with healthy seed stocks. Both the diseased and the healthy seed stocks used for the experiments were of the Green Mountain variety.

Two tubers were harvested each year from each of the hills planted with healthy seed in the rows which were adjacent to the rows having the different diseases. The tuber samples were harvested late in the season when the plants were nearly dead and after the spread of the diseases had occurred. The samples were planted the following spring, and the plants which resulted were examined for the presence of the respective diseases included in the experiment. This procedure permitted the calculation of an index of the relative amount of virus disease spread which occurred during each of the 19 years in which the experiment was conducted.

TABLE 9

Infection in the Green Mountain variety with mild mosaic, leafroll, and spindle tuber in field-exposure plots. Aroostook Farm, Presque Isle, Maine, 1924 to 1942[1]

Year	Mild mosaic[2]		Leafroll[2]		Spindle tuber[2]	
	Number planted	Per cent diseased	Number planted	Per cent diseased	Number planted	Per cent diseased
1924	50	40	50	0	50	10
1925	190	25	192	0	309	10
1926	100	83	22	0	654	1
1927	157	57	52	0	248	2
1928	60	63	40	0	100	0
1929	75	96	75	61	75	61
1930	203	74	74	2	100	0
1931	1628	63	311	9	62	2
1932	184	42	117	11	93	5
1933	993	46	927	2	500	3
1934	675	49				
1935	400	19				
1936	1546	68				
1937	1453	97	20	100		
1938	1490	4	14	14		
1939	1562	72	40	75		
1940	1295	95	40	78		
1941	422	91				
1942	100	708	100	688		

[1] Healthy potato plants were grown in rows adjacent to rows with diseased plants.
[2] Two tubers from each of the plants exposed to the diseases were harvested and planted the following year for determining the extent of virus disease spread.
[3] Based on readings made in the greenhouse.

The results of this experiment have been summarized in Table 9. Mild mosaic, according to the data in Table 9, was disseminated quite extensively every year excepting in 1935 and 1938. The spread of spindle tuber was relatively slight during the 10-year period from 1924 to 1933 excepting in 1929 when 61 per cent of the plants became infected with the disease. The spindle tuber disease was not included in the experiments after 1934 because of its seeming unimportance to the potato industry of Maine.[4]

It should be noted from the data in Table 9 that leafroll was not disseminated in the experiment during the 5-year period from 1924 to 1928 inclusive. The spread of leafroll was great in 1929 (as is also true for spindle tuber) and then was again relatively unimportant from 1930 to 1933.

The leafroll disease was not included in the experiment from 1934 to 1936 because it was considered to be of little economic importance in Aroostook County. However, in 1937, the greatest leafroll epidemic in the history of Maine potato culture was experienced (1 and 2, p. 297).

In 1938, as a result of the 1937 epidemic, some seed stocks were found to be from 70 to 82 per cent infected with leafroll. Rugose mosaic also was spread extensively and from 40 to 60 per cent of some stocks became infected with this disease (1, p. 457). Severe leafroll epidemics occurred also in 1939, 1940, and 1942.

The question naturally arises regarding the reason why the spread of leafroll and spindle tuber was large in 1929 and why leafroll epidemics have become frequent since 1936.

It was observed in 1929 that the foxglove aphid, *Myzus pseudosolani* Theob., was abundant in all of the experimental plots and was the predominating aphid species toward the latter part of the season.[5] The writers do not know how effective the foxglove aphid is as a vector of these diseases in comparison with the other aphid species which occur in Maine potato fields.

[4] Surveys conducted by Drs. Donald Folsom and E. S. Schultz in 1922 and 1923 revealed that the spindle tuber disease was very prevalent and present in most of the seed stocks. Most of the fields had from 15 to 50 per cent spindle tuber and occasional fields had as much as 80 per cent of the disease. Spindle tuber has been practically eliminated from Maine by roguing seed plots and by discarding the diseased seed stocks and replacing them with disease-free seed.

[5] These aphid determinations were made by Edith Patch who at that time was Entomologist of the Maine Agricultural Experiment Station.

It is well known that the green peach aphid, *Myzus persicae* (Sulz.), is a very effective vector of leafroll. Observations made during the period from 1924 to 1930 showed that this aphid appeared every year and generally became the most prevalent species late in the season just prior to the first killing frosts. It is suggested that the more luxuriant growth and longer life of the potato plants and the subsequent longer feeding period of the green peach aphid in recent years has been a big factor in bringing about the increase of leafroll in Aroostook County. Farmers in Maine have increased the life of the potato crop two or three weeks by a more thorough spray program, by the use of heavier applications of fertilizers and lime, and by plowing under large crops of clover. These better farming practices have increased the yield and it is possible that the amount of leafroll spread also has been increased. Late killing frosts also may be a factor in bringing about an increase in the spread of leafroll in some seasons. Longer life of the vines favors leafroll spread by extending the season of feeding by aphids and also by extending the available time for the virus, introduced by insects into the tops, to travel down the stems and reach the tubers.

The seasons of 1937 and 1942 were relatively warm and dry which were factors favoring the rapid development of aphids and a resulting increase in the spread of the virus diseases. The fact that more leafroll infection, from which the disease could spread, has been present in Aroostook County, no doubt also has been a contributing factor for the increase of the disease. Also the curtailment of shipments of leafroll-free seed stocks into Aroostook County has been a factor which has favored the spread of the disease.

DISCUSSION AND CONCLUSIONS

Experience in Maine has shown that susceptible potato varieties rapidly become infected with virus diseases unless they are grown in well-isolated seed plots and are properly rogued. The control of mild mosaic was one of the limiting factors in growing good seed potatoes in Aroostook County prior to 1937. Since 1937, the control of leafroll has been a major problem for the potato industry. The spread of leafroll and rugose mosaic, as well as mild

mosaic and spindle tuber, has been very extensive in recent years. In many cases the spread of these diseases has been disastrous for seed potato growers.

The data for the years 1926 to 1930 show that the inspection records often are only a general criterion of the amount of disease a seed stock will have when it is planted the following year. This is largely because of current-season spread which often is not readily detected by the seed certification inspectors. The information shows that the seed stock of such susceptible varieties as the Green Mountain, Triumph, and Chippewa should be tested for disease content in the greenhouse or in Florida prior to being sold for seed purposes.

The Green Mountain and Triumph varieties, when completely infected with leafroll, spindle tuber, and the different types of mosaic, yielded significantly less than healthy stocks of the same varieties. The yield reductions in both Maine and New York in 1928 resulting from the presence of the above diseases in completely infected seed stocks ranged from 18 to 56 per cent in Maine and from 26 to 64 per cent on Long Island, New York.

Seed stocks with giant hill abnormality yielded slightly more than healthy seed stocks in Maine and 26 per cent less than healthy seed stocks when grown on Long Island. Under Maine conditions spindle tuber, mild mosaic, and leafrolling mosaic in Green Mountains caused a reduction in yield of 18, 22, and 27 per cent respectively, and crinkle mosaic, rugose mosaic, and leafroll reduced the yield rate 46, 50, and 45 per cent respectively. On Long Island, spindle tuber reduced the yield rate in Green Mountains 42 per cent and leafroll reduced the yield rate 53 per cent.

The Triumph variety yielded more on Long Island than did Green Mountain. Mild mosaic in this variety reduced the yield 22 per cent in Maine and 24 per cent in New York, and leafroll reduced the yield rate 56 per cent in Maine compared with 64 per cent in New York.

The same amount of mild mosaic or spindle tuber, when present in the seed stocks, reduced the yield generally more severely on Long Island than in Maine. As a rule the smaller the amount of disease the higher was the yield The amount of reduction caused by the different percentages of disease varied considerably for the different years.

The reduction in yield caused by the presence of the different

virus diseases in the seed stock varies from season to season and from locality to locality. The results of the studies reported here confirm those previously conducted in Maine, that the loss in yield caused by relatively low percentages of virus diseases is not always in proportion to the amount of disease that is present in the seed stock that is planted.

In 1927, an Irish Cobbler seed stock with 6.6 per cent spindle tuber yielded 2.1 per cent less in Maine, and 22.5 per cent less on Long Island, than did the healthy seed stock. In 1929, a seed stock with 3.9 per cent spindle tuber yielded slightly more than the healthy stock when grown in Maine and 19.9 per cent less than the healthy stock when grown on Long Island, New York.

In experiments conducted in Maine in 1938, leafroll did not reduce the yield rate in the Irish Cobbler variety significantly until about 20 per cent of the plants were infected. In the Green Mountain variety, 12 per cent leafroll in the seed stock caused a significant reduction in yield. It should be noted, however, that leafroll infection up to 25 per cent of the plants reduced the yield rate only slightly more than when 12 per cent of the plants were infected.

Mild mosaic in 1939 did not reduce the yield significantly in Maine until 30 per cent of the plants were infected. Rugose mosaic affected the yield rate when 12 per cent of the plants had the disease. The presence of 12 per cent leafroll reduced the yield significantly in the Green Mountain variety. In contrast 20 per cent leafroll did not materially reduce the yield in the Chippewa variety and the presence of leafroll up to 30 per cent of the plants did not appear to reduce the yield significantly in the Irish Cobbler variety.

There were some cases in which the seed lots with more or less disease yielded more than the seed lots that were entirely healthy or nearly so. This occurred in seasons when the fields lacked sufficient moisture to properly mature the crop. In these cases the diseased plants matured early in the season and then permitted the adjacent healthy plants to continue to grow and to increase the crop sufficiently to affect the yield rate.

Experiments were conducted during the 19-year period from 1924 to 1942 for the purpose of securing information regarding the spread of the different virus diseases in Aroostook County, Maine. Mild mosaic was disseminated quite extensively in all of the years included in the experiment excepting in 1935 and 1938. The spread of leafroll in contrast was negligible from 1924 to 1937 excepting

in 1929. The writers are of the opinion that the longer growing period of the potato plants in recent years caused by better spraying programs, the use of more fertilizer and the plowing under of heavy crops of clover may be a factor in bringing about an increase in the dissemination of leafroll. This longer growth of plants has permitted a larger population of the peach aphid to develop and a correspondingly longer period of time in which this aphid was allowed to feed on the potato plants and in which an introduced virus could pass to the tubers. Favorable temperature conditions for aphids also may have contributed to the spread of leafroll and other virus diseases.

The results of these studies show that the presence of a limited amount of the virus diseases may not materially influence the yield. This is a fact that often is not appreciated by many potato growers. The fact that 10, 20 or even 30 per cent diseased plants may not greatly reduce the yield should not be regarded as a reason for discouraging the control of the virus diseases. It has been shown that when aphids are numerous a seed stock with 1 to 10 per cent mosaic or leafroll one season may have 50 per cent or more of the plants infected the following season. Moreover, losses from leafroll are greater than the mere reductions in yield indicate, because current-season infection of leafroll causes net necrosis in the tubers of Green Mountain, Irish Cobbler, and similarly reacting varieties, which disqualifies such affected varieties not only for seed potatoes but also for first-class table stock.

This clearly emphasizes the importance of practical control measures for the production of disease-free seed potatoes. In other words, the slogan of the seed-potato grower *must not be,* "How much disease can I tolerate to get by?" Instead his slogan should be, *"Disease-free seed potatoes."* The production of disease-free seed potatoes promotes satisfactory results for the grower and buyer of seed potatoes and is the best recommendation for a seed-potato-growing region or the individual farmer.

SUMMARY

The results of this bulletin show the effect of season, locality, and different percentages of the virus diseases on the yield of potatoes when raised on Long Island, New York, and in Aroostook County, Maine. The variation in virus disease spread in Maine is given for the 19-year period, 1924 to 1942 inclusive.

The spread of the virus diseases varies from season to season. In Maine the spread of mild mosaic for the 19-year period varied from 4 to 97 per cent, leafroll from 2 to 100 per cent, and spindle tuber from 1 to 61 per cent. The most extensive spread of the virus diseases occurred in seasons which were most favorable for the insect vectors.

The data for 1926 to 1930 show that the certification inspectors' field records often are not reliable in determining the amount of virus disease a seed stock will have when it is planted the following year. Masking of symptoms and late current-season infection make accurate predictions of the extent of virus diseases in seed stocks impossible. Other studies conducted in Maine have shown that advance testing of representative tuber samples of seed stocks either in the greenhouse or in the South will give a good index of the virus disease content.

The Green Mountain and Triumph (Bliss Triumph) varieties, when completely infected with leafroll, spindle tuber, and the different types of mosaic, yielded significantly less than healthy stocks of the same varieties. The yield reduction in 1928, resulting from complete infection by these diseases, ranged between 18 and 56 per cent in Maine and between 26 and 64 per cent on Long Island, New York. Leafroll and spindle tuber reduced the yield rate more on Long Island than in Maine.

Giant hill, a late-maturing mutant of the Green Mountain variety, yielded slightly more than did the Green Mountain variety in Maine but yielded less on Long Island. Triumph, an early variety, outyielded the Green Mountain variety on Long Island, indicating that the conditions on Long Island were more favorable for the earlier maturing varieties in 1928.

Relatively low percentages of the virus diseases were not necessarily conducive to reductions in yield. Differences in yield between seed stocks that varied little in amount of disease apparently

were caused by other factors than the virus diseases that were present.

The reduction in yield was not always directly proportionate to the amount of virus disease that was present.

Yield reductions resulting from planting seed stocks harboring different percentages of virus diseases are influenced by varietal and seasonal conditions as well as by the location. In Maine in 1938 and 1939, leafroll did not reduce significantly the yield in the Irish Cobbler variety until from 20 to 30 per cent of the plants were infected, while in the Green Mountain variety a significant yield reduction occurred when 12 per cent of the plants were infected. In 1939 less than 30 per cent mild mosaic did not significantly reduce the yield while 12 per cent rugose mosaic did significantly reduce the yield in the Green Mountain variety.

The fact that leafroll has spread more extensively since 1937 may be attributed in part to the fact that the potato fields have been kept in a growing condition for longer periods of time than in previous years through improved cultural practices. This later maturity of the potato plants has allowed a longer feeding period for the green peach aphid, which might have resulted in more leafroll being disseminated, and a longer period for the virus to pass from leaves through stems to tubers.

The fact that the presence of relatively low percentages of the virus diseases in the seed stocks may not significantly reduce the yield should not be regarded as a reason for discouraging the control of these diseases. Experience has shown that when insect vectors are numerous, seed stocks with from 1 to 5 per cent mosaic or leafroll may have 50 or 100 per cent diseased plants the following year. Therefore, the slogan of the seed potato grower *must not be,* "How much disease can I tolerate to get by?" His slogan should be, *"I will raise disease-free seed potatoes."* This attitude will give more satisfactory results both for the producer and the buyer.

LITERATURE CITED

1. Bonde, Reiner. Observations on the prevalence of potato diseases in Maine during 1938. Plant Disease Reporter 22: 457-460. 1938.
2. ————. Spread of virus diseases in 1937 in Aroostook County. In Report for 1937-1938. Me. Agr. Exp. Sta. Bul. 391: 297-298. 1938.
3. Blodgett, F. M. A method for the determination of losses due to diseased or missing plants. Amer. Potato Jour. 18: 132-135. 1941.
4. Eddins, A. H. Studies relative to disease control of white (Irish) potatoes. In Fla. annual report for fiscal year ending June 30, 1940, pp. 105-106. 1940.
5. Folsom, Donald. Potato leafroll. Me. Agr. Exp. Sta. Bul. 297. 1921.
6. ————, E. S. Shultz, and Reiner Bonde. Potato degeneration diseases: Natural spread and effect upon yield. Me. Agr. Exp. Sta. Bul. 331. 1926.
7. Schultz, E. S., and Donald Folsom. Transmission, variation, and control of certain degeneration diseases of Irish potatoes. Jour. Agr. Res. 25: 43-118 and 15 plates. 1923.
8. ————, Reiner Bonde, and W. P. Raleigh. Isolated tuber-unit seed plots for the control of potato virus diseases and blackleg in northern Maine. Me. Agr. Exp. Sta. Bul. 370. 1934.
9. Smith, K. M. A textbook of plant virus diseases. Phila., P. Blakiston's Son and Co., Inc. 1937.
10. Tuthill, C. S., and Phares Decker. Losses in yield caused by leaf roll of potatoes. Amer. Potato Jour. 18: 136-139. 1941.